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PROPOSED SITING CRITERIA FOR LOW-LEVEL RADIOACTIVE WASTE FACILITIES IN MASSACHUSETTS

Prepared for

The Executive Office of Environmental Affairs

and the

Massachusetts Health Research Institute

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Executive Summary

The first step in the siting process for low-level radioactive waste disposal is to develop a list of siting criteria. The federal Nuclear Regulatory Commission (NRC) has promulgated regulations which contain site suitability characteristics for shallow land disposal facilities. That is only one of several alternative technologies currently under consideration. Above-ground engineered storage is another technology thought to be feasible. The high water table, humid climate, and geology of Massachusetts tend to favor engineered storage for several reasons.

- More sites would be available since some site suitability criteria could be more easily met by engineered storage.

- A shallow land disposal facility would have trouble meeting the NRC performance standards for prevention of water contacting the wastes, buffer zones beneath buried waste, water infiltration into trenches, and off-site migration of radioactive wastes. Generally, engineered storage can meet or exceed the NRC regulations more easily than can land burial.

- Above-ground facilities are easier to monitor, leaks can be contained, and the wastes can be retrieved more readily in the event of an emergency.

The siting criteria must work in conjuction with rigorous facility operation and waste management requirements. Without these additional standards, the siting criteria become meaningless. Perhaps one of the most important management requirements is that all waste be solidified. Many of the

contamination problems that have surfaced elsewhere result from placing unstabilized waste in containers which decompose or corrode. The waste and the containers collapse, leading to subsidence of the trench covers and subsequent contact between water and the wastes. Waste solidification can help rectify this problem.

Long term care is needed to ensure containment of the wastes. The management controls must be in place so that the facility operator knows what wastes are located in each disposal unit. In the event of a release, remedial action can be taken immediately. Accurate record-keeping and constant monitoring is required to detect and pinpoint the source of any release. Finally, site closure and long-term maintenance of the facility must be planned for in advance along with the establishment of a funding mechanism to cover any future costs.

Public participation must be intregral to the siting process, built in to every stage: planning and policy formulation; promulgating regulations; reviewing specific potential sites; evaluating proposed facilities; setting management and operational requirements; and monitoring compliance and instituting further safeguards as needed, including remedial action if safeguards fail.

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1.0 Introduction

As a result of the federal Low-Level Radioactive Waste Policy Act of 1980, Massachusetts must begin to assess its options for dealing with low-level radioactive waste generated in the Commonwealth. Regardless whether the Commonwealth "goes-it-alone" or enters into a multi-state compact, a credible siting process must be established in order for a disposal or storage facility to be contemplated. Prior to developing the siting process, it is important to identify the criteria that will be applied to any proposed system of waste management in order to determine its capability to isolate the waste from the environment. The purpose of this report is to identify and analyze those criteria. We do not assuemt there will be a site.

In this report, we have developed a list of siting criteria designed to address the concerns raised at the six shallow land burial sites across the country. Our goal is to develop a list that would ensure, to the extent feasible, that wastes which are disposed of do not contaminate the environment in and around the site. Additionally, we have addressed a number of non-site specific issues such as waste preparation, facility operation and monitoring, financial capability of the licensee, and a tracking system following the waste from the point of generation to its ultimate disposal. We believe that management criteria are vital because siting criteria alone, even if properly applied, become meaningless if proper management procedures are not followed.

Sloppy handling of wastes or the mismanagement of the facility can result in significant environmental damage, even if it is located on a good site.

In January, 1983, the Nuclear Regulatory Commission (NRC) promulgated regulations for the siting of shallow land burial facilities to dispose of low-level waste (10 CFR Part 61). One objective of this report is to compare proposed criteria with these NRC regulations to determine where a state requirement may differ from those of the NRC. Thus far, the NRC has promulgated regulations only for land disposal which involves the packaging and underground burial of wastes within a depth of 30 meters. Other technologies are considered feasible alternatives, and NRC may promulgate additional regulations. Therefore, another objective of this report is to consider criteria that are applicable to other technologies.

Shallow-land burial is the only technology that has been employed to date. Generally, wastes are buried in trenches that range from 200-1000 feet long, 20-60 feet wide, and 20-30 feet deep. Wastes are buried in a variety of containers, such as boxes, drums or casks. Once a trench is filled with waste, it is backfilled, compacted and covered with a cap. The cap should consist of layers of clay to prevent infiltration and then covered with soil and grass to ensure stability. Intermediate-depth land burial is a variation of this technology in which the wastes are covered with more fill and soil. Subsequently, the thickness of the trench caps would increase.

There are three shallow-land burial sites that still accept waste (Hanford, WA, Beatty, NV, and Barnwell, SC). Three sites have failed and are shut down (West Valley, NY, Sheffield, IL, and Maxey Flats, KY). While all facilities have had problems with improper packaging and leaky shipments, the three closed disposal sites have had chronic difficulties ranging from trench cap collapse and subsidence to water collecting in the trenches and the leaching of radionuclides. A mixture of design and operation failures, poor site characteristics, and waste instability are at the root of these problems.

One alternative that has been receiving a good deal of consideration is engineered above-ground storage. Segregated wastes would be stored in tanks or barrels above ground in concrete bunkers or vaults appropriately sheltered to avoid accidental releases into the environment. Monitoring of the waste and the site would be made easier with this approach. The wastes would be retrievable in the event of a leak or structural failure of the facility. An engineered barrier would help to isolate wastes from the environment. The structures could be built either above or below ground.

Another advantage to above-ground storage would be that more potential sites for a facility would be available since an engineered structure would not be required to meet the stricter criteria needed for developing a shallow-land burial site. This is particularly important for Massachusetts, since much of its

land area would be precluded from hosting a shallow-land burial facility due to geological, climatogical and demographic concerns. Our report will develop the siting criteria which could be applied to above-ground storage.

Several forms of volume reduction have been utilized by industry. Incineration of wastes will reduce the volume by creating ashes, although air emissions are a problem. Waste compaction will also reduce the volume, but will increase the concentration of radioactivity. Finally, some generators have used various techniques such as reclamation to reduce their wastes.

There are other alternatives that have been utilized or studied. One is deep mine disposal, where the wastes are buried hundreds of feet below ground in abandoned mines. Both normal waste handling equipment and conventional mining equipment would be used under this system. It is unlikely that a suitable mine would exist in Massachusetts. Another alternative is ocean dumping. Low-level waste has been deposited in the oceans for years, but was suspended in 1971. It is highly controversial and generally not accepted within the environmental community. We have not covered these alternatives in our report since they will not provide a solution within the time necessary under the Low-Level Radioactive Waste Policy Act.

2.0 Description of the Pathway for Potential Contamination

This section of the report identifies the numerous pathways by which potential contamination can enter the environment and endanger human health. The purpose in identifying these pathways is to propose criteria for managing the wastes and siting a facility which will ensure that radioactivity from wastes does not create environmental problems in the future. Release of radionuclides can occur at any point in the waste disposal process. To illustrate this point, we have prepared schematic diagrams which trace the waste material from the point of generation to its ultimate disposal. The diagrams appear at the end of this section.

2.1 Direct Contact

Human interaction with the low-level radioactive waste can occur in a number of ways. Occupational exposure to the waste is a risk during every step of the disposal process. This is particularly true in packaging and disposal. Radiation dose limits for occupational exposure are discussed in Section 3.6. In order to minimize these exposures, proper management procedures must be followed throughout the entire disposal process.

In emergency situations, such as a transportation accident or an on-site spill, the threat of direct exposure to radiation

is great. Once the wastes have breached their containers, immediate exposure will result to those involved in the accident or spill and to the people involved in the clean-up. Additional exposure will occur in the longer term through the air, land and water.

"Inadvertant intrusion" of a disposal site occurs where buried wastes are excavated without prior knowledge of their existence. Unmarked disposal sites make this a real possibility. If the wastes have not deteriorated, the excavator could be exposed to doses of radiation.

Finally, direct human contact with contaminated wastes occurs when there is "intentional" intrusion on the disposal site. This is an issue which is not covered in the NRC regulations. An example of this kind of intrusion would be people searching for tools, test tubes and other disposed items that are stored on the site. This has happened a number of times in the six licensed disposal facilities. We propose criteria to limit intentional and unintentional intrusion on-site in Section 3.11.

2.2 Air

Releases of radioactivity into the air is one of the more crucial pathways for contamination to enter the environment. One of the more significant problems is the inability to contain these releases once they occur. The release immediately will

disperse and spread out over a large area of land, thereby creating the potential for exposing many people. Releases into the air most likely will occur as a result of poor management practices. Improperly contained wastes will emit radiation into the ambient air, posing a threat to those who work with the waste materials. Certainly the most severe conditions will emanate from transportation accidents, fires or on-site spills of waste. Immediate action is required in order to contain the spill and limit the extent of the contamination.

Normal stack emissions from incinerators as well as emissions from inherently volatile isotopes (such as tritium, carbon 14 and iodine) also can add radionuclides into the atmosphere. Incineration of low-level radioactive wastes is utilized as a controversial method of volume reduction. There are ways in which to reduce the emission levels from the volatile and incinerated wastes.

2.3 Surface and Ground Water

Most of the problems that have occurred at the three closed facilities are related to the leaching of radionuclides out of the trenches and into the groundwater. This results from a combination of improper management or packaging of the wastes and poor site suitability. The three facilities that failed provide valuable lessons in developing siting criteria needed to isolate the wastes from the environment. It is important to note that

each of these facilities is located in a humid climate, which exacerbates the conditions leading to the leaching of contaminants. This problem, of course, is one that Massachusetts faces as well.

At Maxey Flats, the trench-capping material was more permeable than the surrounding soil and underlying shale. Many of the metal containers which held the wastes corroded and the trash and organic waste decomposed. This weakened the caps, causing subsidence of the trench covers. As a result, surface water runoff was impeded and water collected in the trenches. The wastes continually were exposed to the leaching of radionuclides. Some lateral migration of radionuclides has been documented. Detectable levels of tritium, strontium, plutonium and cobalt have been discovered outside the boundaries of the site, which was closed when mitigation measures failed.

The Sheffield site is located in an area which consists of 5 to 20 meters of glacial sand, silt and gravel over an underlying bedrock layer of shale, claystone, sandstone and coal. The upper sediments are permeable, which allowed the accumulation of water in the trenches. A regional aquifer is found approximately 100 feet below the ground surface. The water table is anywhere from 5 to 10 meters below the ground surface. Recent discoveries of tritium migration through the groundwater pathways has led to the closure of the facility.

The West Valley reprocessing plant site was not originally planned to be a burial ground, but 25 acres are now occupied by

low-level wastes. There are also high level wastes buried on site and some solid waste. In the spring of 1975, some seepage from the site was detected. Water had infiltrated the trenches and the integrity of the trench caps could not be maintained. Waste decomposition and compaction in the trenches weakened the caps. The trenches were excavated in soils with low permeability and a "bathtub" effect was created as water accumulated in the trenches. The water level eventually rose to the top and seeped through the caps. Additional problems occurred because of sand lenses in the trench where radionuclides leached out of the trenches into nearby streams. Erosion from nearby streams and gullies also exacerbated the situation. Water infiltration is still a problem despite efforts to rework the trench caps. There is some fear of contamination to nearby water bodies and groundwater.

We can learn some valuable lessons from these problems. A combination of site stability and proper waste packaging or solidification can protect against the leaching of radionuclides from the trenches that are designed to contain them. Throughout this report, recommendations are made to correct the site and operational deficiencies that led to the environmental nightmares at Maxey Flats, Sheffield and West Valley.

2.4 Transportation

Transportation is the link in the management of wastes from its original point of generation to its destination for disposal. Key elements in the transportation process must be addressed in developing a sound waste management plan.

The major pathway for contamination during transportation is an accident. Radionuclides can enter the atmosphere, water or land resources. While no standards can guarantee that accidents will not happen, several precautions can be taken to avoid them or reduce the potential damage in the event one occurs.

One of the criteria that should be used in screening potential sites for development is the transportation network serving the facility. Just as a site should be isolated from population centers, routes on which waste-bearing trucks travel also must be isolated from areas which present greater risks of an accident. Secondly, the packaging of the waste material must be managed properly from the point of generation so that, if an accident occurs, the waste material does not disperse into the environment. Finally, there is a need for effective remedial action plans to decrease the consequences of an accident. Section 3.4 will address many of these issues.

2.5 Biota

Inadvertent intrusion into low-level radioactive waste sites occur when flora and fauna come into contact with waste material.

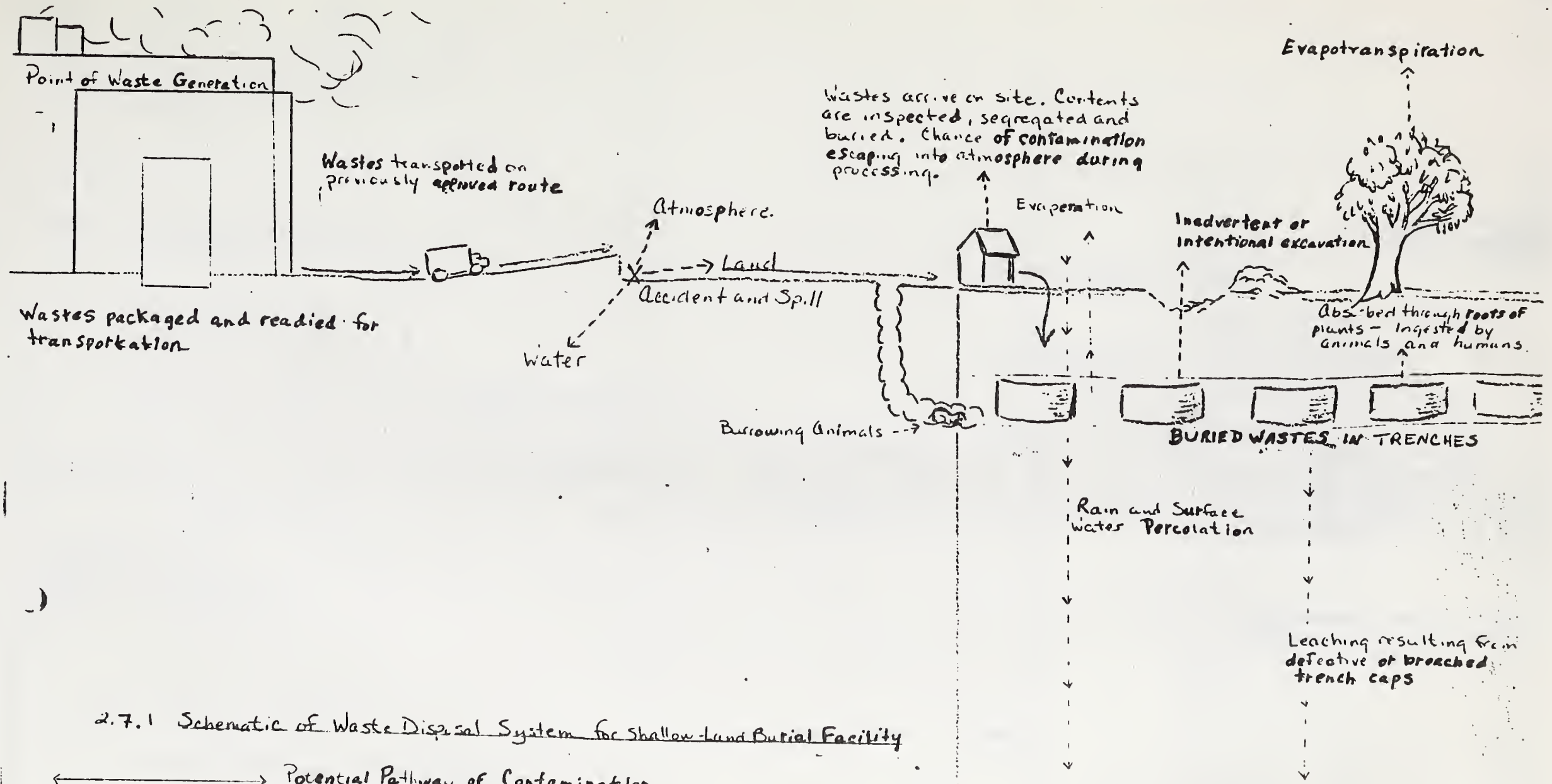
Experience at the six shallow-land burial sites show that radioactive contaminants can be absorbed by plants through their roots. Small animals, particularly ones that burrow, can come into contact with buried waste material. They subsequently may spread the radionuclides elsewhere.

This problem can be compounded by the role that a particular plant or animal plays in the food chain. Contamination will spread as it concentrates in the tissues of animals in the higher levels of the food chain. This, of course, can include human consumption of fish, meat or agricultural products that contain some degree of radioactivity within the tissues. We will cover these concerns in Section 3.9.

2.6 Emergency Situations

A number of emergency situations can arise which have the potential for adversely affecting the environment. They fall into two major categories - a "sudden" or accidental release and a "non-sudden" release. Spills and transportation accidents are examples of releases which can be contained and cleaned up without much delay. Non-sudden releases such as the leaching of radionuclides through the groundwater, however, require detailed investigation and study to determine the breadth of the contamination and the method for containing it and reducing the environmental harm. These releases usually go undetected until significant harm has occurred.

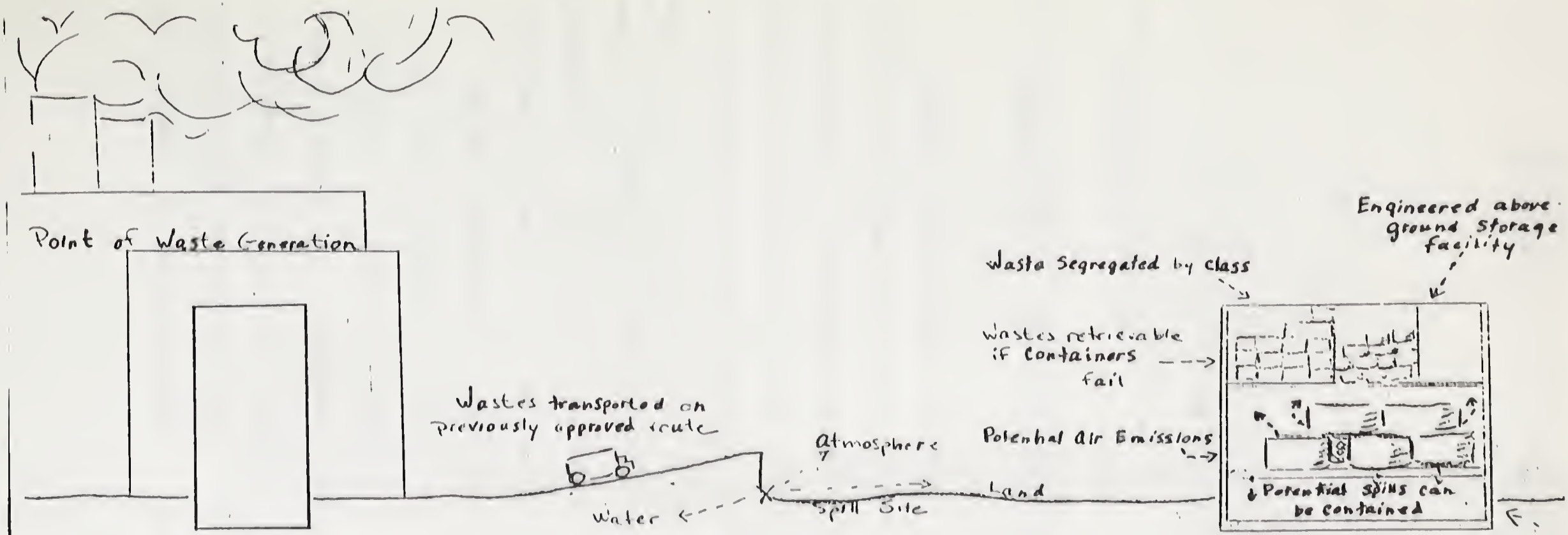
Regardless of the type of release, all have the ability to impact any portion of the ecosystem and should be viewed as potential threats to public health. Proper management and operational procedures combined with effective remedial action plans are required to lessen the chances of a release.


Point of Waste Generation
Wastes transported on previously approved route
Wastes packaged and readied for transportation
Atmosphere.
Land
Accident and Spill
Water
Wastes arrive on site. Contents are inspected, segregated and buried. Chance of contamination escaping into atmosphere during processing.
Evaporation
Evapotranspiration
Inadvertent or intentional excavation
Absorbed through roots of plants — ingested by animals and humans
Burrowing Animals
BURIED WASTES IN TRENCHES
Rain and Surface water Percolation
Leaching resulting from defective or breached trench caps
GROUNDWATER
Lateral transport by Groundwater
Disposal Site

2.7.1 Schematic of Waste Disposal System for Shallow-Land Burial Facility

←——→ Potential Pathway of Contamination

←——→ Waste Disposal system (for a Shallow-Land Burial Facility)



2.7.2 Schematic of Waste Disposal System for Engineered Above-Ground Storage

<---> Potential Pathway of Contamination

<---> Waste disposal System

3.0 Criteria Groupings

3.1 Waste Tracking System/Surveillance of Generators

Federal regulations, found at 10 CFR 20.311, describe the transfer of wastes for disposal and the preparation and distribution of tracking documents known as manifests. The manifest is designed to track the waste from its point of origin to its destination for disposal ("cradle to grave"). It is a useful tool for learning what types of wastes are generated and where, how they are transported, and how they are ultimately disposed of. The manifest creates a paper trail which becomes important if there is an emergency or if a shipment is lost.

The NRC regulations stipulate that a manifest must be filled out for every shipment of waste and that it must contain certain information including the names of the generator, transporter and disposal facility, a physical description of the waste (including its volume, radionuclide content and radioactivity) and the chemical form of the material. The manifest is used to verify the contents of each shipment. A copy is signed and retained by

each party involved in the shipment. The Massachusetts Hazardous Waste Regulations include a manifest procedure (310 CMR 30.310) which is similar to the NRC requirements, but which is more comprehensive. This tracking system requires that the Department of Environmental Quality Engineering (DEQE) receive copies of the manifest from the generator and from the disposal facility owner or operator. This allows for more careful monitoring of the waste disposal process. The Commonwealth's planning and emergency response efforts would be further enhanced by knowing what types of wastes are produced and where. We recommend that the Commonwealth adopt a aproach similar to the hazardous waste manifest system.

3.2 Financial

Another non-site specific issue which must be addressed when siting a waste disposal facility is the ability of the developer to build and operate the plant. Past experience at low-level radioactive waste sites, and particularly hazardous waste disposal sites, has shown that in addition to the significant construction costs that would be incurred, there are substantial costs for facility operation, maintenance and insurance. By the time the facility is closed, additional funds are needed for site closure and long term maintenance and monitoring.

The Commonwealth's hazardous waste regulations require that some basic information be provided by the developer prior to the

issuance of permits and licenses to build the facility. Similar requirements should apply to low-level radioactive waste sites. This should include: the cost of the project; the market that the facility is designed to serve; the financing plan for the facility; and the financial composition of the company (i.e. subsidiaries and parent corporations). There are not specified in the NRC regulations. (See Section 61.15). The developer also should show that it has sufficient financial resources to construct or expand the facility; provide operational and maintenance control to abide by all pertinent laws, regulations, and ordinances; insure the facility and its environment against immediate and slow releases of contamination; and provide a funding mechanism (bonding, trust fund, or other surety) to cover releases into the environment, closure and post-closure maintenance. Sections 61.61-3 of the NRC regulations address some of these issues.

Regardless of the technology employed in Massachusetts, we will be faced with a situation where long term care (several hundred years) is needed to ensure isolation of the wastes from the environment. This is difficult to guarantee for that period of time. It is important, however, that the developer be required to show that it has the financial capability to provide the necessary long-term care and maintenance for a substantial period of time.

3.3 Waste Characterization

The segregation and solidification of wastes are important considerations in the operation of any low-level waste facility. The NRC regulations require that wastes in the three classes be segregated in different disposal units. Only Class A wastes do not require solidification.

At the three sites that have failed, one common problem has been the decomposition of waste materials and their containers. This is particularly true of Class A wastes, which comprise about 60% of the waste stream by volume.[1] Decomposition of containers increases risk of leaching radionuclides from the wastes that are now exposed within the trench. When the wastes are not solidified, there is a significant danger of contamination entering into the groundwater. Therefore, it seems prudent to solidify all wastes, especially if land disposal is the preferred alternative. Although engineered disposal will help to alleviate this problem, waste segregation and solidification should be required for all classes of wastes and for any technology that is employed.

Criteria for Waste Characterization

Proposed Criteria	Comparison with NRC 10 CFR 61	Comments
All wastes must be segregated at the point of generation and must	Not entirely specified	Since the wastes have a variety of different characteristics

Proposed Criteria	Comparison with NRC 10 CFR 61	Comments
be disposed of in separate disposal units.		and require different storage techniques, they should be segregated at the source and remain that way through disposal. Depending on the source, the wastes vary in volume, form, and radioactivity. During disposal, the classes of wastes should be segregated (separate trenches for land disposal, and separate "rooms" for engineered disposal).
All Class A wastes should be solidified.	Not specified	Particularly important for land disposal in order to avoid leaching if container decomposes. More costly in the short run, but more beneficial in the long run from an environmental and economical viewpoint. Solidification should also be required for waste disposal in engineered structures in order to ensure stability. Numerous methods are available such as concrete, polymers, etc.

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1. Shillen, James, et al., Low-Level Radioactive Waste Overview, Pennsylvania State University, 1984, p. 3.

3.4 Transporation

Hospitals, medical, educational or governmental research facilities, nuclear power plants, and other industries and utitlites that use radioactive materials as part of their operations generate significant quantities of low level radioactive wastes each year. It is estimated that there are over 3 million shipments of radioactive materials each year in the U.S. originating from over 20,000 different facilities. They are carried by trucks, planes, trains and even the U.S. postal system.[1] Many of these shipments contain radiopharmaceuticals and other radioactive materials for use in medical research studies and the manufacture of consumer products. On the other hand, many of these shipments contain the waste by-products of these activities and come in a variety of forms. The forms of low-level radioactive wastes from hospitals and research laboratories, for example, include dry solids (protective clothing, syringes, containers, small tools, plastics); liquid-scintillation wastes (usually toluene and contained in a glass vial); organic liquids (laboratory solvents); biological wastes (animal carcasses); and gaseous wastes (used in studying lung capacities). Tritium, with a half-life of 12.3 years, is the principal radionuclide found in hospital and laboratory research wastes.[2] The low-level radioactive waste generated by nuclear power reactors also comes in various forms, including dry trash (protective clothing, construction/insulation materials),

plant equipment (piping valves, and so forth) and wet wastes (sludge from filtering the reactor water). The radioactive wastes from industrial uses of radioactive materials also include solids, liquids and gases. The nature of this waste is difficult to describe, however, because of the variety of industrial processes and radioisotopes in use. It is estimated that approximately 90 percent of all radioactive shipments are made using Type A packages, with Type B packages (9.7%), drums (0.3%) and casks (0.1%) accounting for the smaller percentages.[3]

Despite the significant number of radioactive materials shipments made each year[4], the safety record in their transport is considered excellent. During the period 1971-1981, there were only 38 reported incidents nationwide which resulted in the release of radioactive materials and all involved Type A packages containing lower quantities of radioactive materials. In the 10 incidents involving Type B packages (higher quantities) of radioactive materials, there were no releases. There have been no reported deaths or clinical evidence of injury attributable to the release of radioactive materials in transport.[5]

Some would argue that, when considering the necessary transportation issues associated with the siting of a low-level radioactive waste disposal facility, concerns for possible accidents may be offset by the safety record of the radioactive materials traansport industry. There is evidence, however, to conclude that the number of incidents which have actually occurred during the transport of radioactive materials is

significantly higher than the number reported.[6] There is also evidence to support the conclusion that radioactive waste shipments present special problems because, having no economic value, they offer less economic incentive to ensure their proper packaging and transport. A closer look at the experiences of the states that now host low-level radioactive waste disposal sites reveals a number of issues which must be addressed in the siting process. In 1979, for example, both the states of Nevada and Washington temporarily closed their disposal sites because of violations of radioactive waste transportation regulations.[7] This led the governors of all of the host states, including Nevada, Washington and South Carolina to make a public call for increased federal inspections and enforcement of the transport inspections at disposal sites. In Nevada, the problems with shipments have been particularly persistent. In May, 1979 there was a widely publicized fire on a truck shipment of low-level radioactive wastes, in addition to some leakage of contaminated liquid, en route to the site. As a result, the state initiated its own inspection program and began to find a number of trucks with faulty brakes, brake lights, and other equipment problems. In April, 1981, the State of Nevada also established a requirement for third-party inspections of all packages sent to the disposal facility to insure compliance with state transportation regulations.[8]

With these and other experiences in mind, we can identify a number of criteria which could be imposed upon a siting process

to minimize the dangers associated with the transportation of low-level radioactive wastes. These criteria relate to the categories of waste characterization, transportation, and facility operation and monitoring, and cover a number of topical areas:

Waste Characterization	Packaging Labeling
Transportation	Vehicle Placarding Shipping Papers Alternative Modes and Routes
Facility Operation and Maintenance	Vehicle Inspections and Enforcement Emergency Preparedness

Following is a statement and descriptions of the criteria which apply in each of these areas.

All low-level radioactive waste accepted for disposal at a proposed site should be in containers which meet DOT requirements for proper packaging and containment.

Under the authority of the Hazardous Materials Transportation Act (MHTA) of 1975, (49 U.S.C. 809), DOT has established standards for the packaging of radioactive materials which are designed to minimize contamination, radiation exposure, heat hazard, and criticality.

Contamination refers to direct contact with radioactive materials. Persons handling packages (loading, unloading) are protected by package designs that contain the radioactive materials under the normal stress conditions of transport.

Exposure to radiation refers to the hazards presented by radiation that passes through packaging or shielding. Limits on the quantity or concentration of radionuclides within a package are designed to ensure that there is no excessive radiation on the outside of the package. To meet these standards, shippers and carriers use shielding, special casks and remote handling of the radioactive packages. To prevent exposure, packages are often segregated from persons and property or sent in trucks that are for the "exclusive use" of radioactive materials.

Heat hazards refer to the physical heat given off by irradiated materials. Such hazards are prevented by limits on the quantity and concentration of materials in certain packages, by package design, remote handling or the ventilation of freight containers.

Criticality refers to the possibility of sufficient fissionable materials being in one location to result in a nuclear chain reaction. NRC rules adopted by DOT limit the amounts of fissionable materials that can be placed in a single container or package.

Title 49, Part 173, of the Code of Federal Regulations defines classifications for transport packages, sets packaging standards, and specifies the allowable limits of radiological hazard of the package surface. In general, packaging requirements vary based upon the amount, form and concentration of the radioactive waste being shipped. The types of packages that may be required include:

Industrial Packages - include fiberboard, wooden boxes and other strong, tight packaging. The use of industrial packages is limited to shipments of radioactive materials with low specific activity because they contain few radioactive curies.

Type A Packages - must meet DOT tests and criteria designed to simulate the potential stress on the package for rough handling and minor transportation mishaps. These tests include water spraying, drop tests, and crush and penetration tests. Type A packages are also subject to

limits on the quantities of radioisotopes in any one package. These limits are very detailed and based upon the degree of hazard associated with over 250 radionuclides identified in the regulations. Type A packages must also meet certain general standards related to the seals of the package and the amount of absorbent materials required (radioactive liquids). These general standards further require that packages be designed to be "easily decontaminated", resistant to extreme temperatures, and designed to minimize any hazard that might result from the mixing of materials in a container.

Type B Packages - must meet all the design requirements of Type A packages and additional, more severe accident tests.

DOT regulations also limit the amount of radiation emitted from packages during transport. (49 CFR 173.389-173.398). Because some penetrating radiation is only partially absorbed by containment and shielding systems, freight handlers, truck drivers and others may be exposed to radiation if they are close to or in contact with the packaging. Radiation controls, expressed in the form of a "transportation index"[9], require shippers to provide shielding or carriers to rely on remote handling in order to reduce the hazards of exposure to radiation.

All low-level radioactive waste accepted for disposal at a proposed site should be transported only in packages which meet DOT labeling requirements.

Under the requirements of 49 CFR 172.403, every package or container of radioactive waste, except for small quantities, must have a standardized label, coded for the degree of radiological hazard and showing the radionuclide content and number of curies.

All low-level radioactive waste accepted for disposal at a proposed site should be transported in vehicles that comply fully with DOT placarding requirements and contain shipping papers.

In addition to the packaging and labeling requirements, DOT requires that carriers comply with vehicle placarding requirements (49 CFR 172.556). These requirements specify that each motor vehicle, rail car or freight container for radioactive materials be placarded on each end and each side with placards of a standardized design and color. Shippers of radioactive wastes are also required under 40 CFR 172.203(d) to carry shipping papers that include the name of the shipper, name of the radionuclides being shipped, amount of activity in each package, and labeling and warning information.

The host state -- indeed every state in the case of a regional compact -- should initiate a comprehensive inspection and enforcement program that targets radioactive waste shippers and carriers. As necessary, there should also be a third-party inspection to ensure compliance with the above transportation regulations.

The primary protections from radiation hazards during transport is provided by the design of packages and shielded containers described above. These packaging safeguards are supplemented by limits on the concentration of radioactive shipments, by special rules applicable to fissionable materials, and by driver training and other operational requirements. As evidenced by the experiences to date at the Beatty, Neveda disposal site, however, shippers and carriers may not always comply with all appropriate practices. Most businesses affected by the federal radioactive materials transportation regulations,

or by similar state regulations, comply with them most of the time. There are always some businesses, however, that will violate safe radioactive waste handling, shipping and transport practices. A broad and continuing education program conducted by the host state (or all of the generating states) can go a long way in addressing this problem by informing industry of the requirement it must meet. A few businesses, however, may purposely violate applicable radioactive waste transport regulations because they either (a) fundamentally disagree with them, or (b) cannot comply and stay in business. With the large start-up costs involved in the transport industry, young companies often find it particularly difficult to comply with the letter of every regulation.[10]

To address this problem, any state in which the radioactive wastes are being transported should develop and implement effective inspection and enforcement programs. These programs should be supported by proper legal authorities and properly trained and equipped inspection personnel. In Illinois, for example, special training has been given to over 45 state troopers who now devote their time to enforcing regulations on highway shipments. Although the majority of inspection conducted by the troopers are of non-radioactive hazardous material cargoes, they are equipped and trained to use sophisticated radiation monitoring equipment.

The state of Florida has gone even further by passing a law that requires the Department of Health and Rehabilitative Services to inspect all shipments of low-level radioactive wastes

to storage or disposal facilities. As part of Florida's inspection program, there are requirements for (a) advanced notification prior to the shipment of radioactive wastes; (b) detailed inspections of shipping papers, labeling, marking, placarding, package security seals, and package tests; and (c) the tracking of waste shipments from origin to destination by means of a detailed record keeping system.

In the case of a regional impact for low-level radioactive waste disposal, each state that is party to the contract should be required "to establish the capability to enforce any applicable federal or state laws and regulations pertaining to the packaging and transport of wastes generated within or passing through its borders".[11] Some regional compacts define the specific responsibilities of the participating states in detail. For example, the Rocky Mountain Compact for low-level radioactive waste disposal requires that each state in the compact to:[12]

(1) Agree to adopt and enforce procedures requiring low-level waste shipments originating within its borders and destined for a regional facility to conform to all packaging and transportation regulations. Such procedures shall include but are not limited to:

(a) periodic inspections of packaging and shipping practices;

(b) periodic inspections of waste containers while in the custody of carriers; and

(c) appropriate enforcement actions.

(2) Agree that after receiving notifications from a host state that a person in the party state has violated packaging, shipping or transportation requirements, it shall take steps to ensure the violation does not recur. Appropriate action may include, but is not limited to, the requirement

that a bond be posted by the violator to pay the cost of repacking at the regional facility, or that all future shipments be inspected.

(3) Agree to allow the imposition of fees to recover the cost of the practices provided for in paragrphs (1) and (2); and

(4) Agree to maintain an inventory of all generators within the state that may have low-level waste to be disposed of at a regional facility.

The site of any low-level radioactive waste disposal facility should be located as close as possible to the bulk of the waste generators so that no carrier has to transport extremely long distances (as is the current practice) over high risk roadways (or railroad track) and through heavily populated areas.

Of course, even the most comprehensive inspection and enforcement program will not eliminate entirely the risks associated with the movements of radioactive wastes. It is therefore extremely important that the transportation modes and routes available for transporting the low-level waste to a disposal site be a key criterion in evaluating sites for the location of a low-level radioactive waste facility. By creating state or regional disposal facilities, with their attendant proximity to the waste generators, the risks of possible transportation accidents and the costs of transporting the wastes can both be relieved.

A number of guidelines have been developed to assist a state in identifying the highway routes which, if traveled, would present the least risk to people and property.[13, 14, 15, 16] The guidelines, in turn, identify a number of criteria which should be considered in the evaluation of alternative routes. These same guidelines and criteria can be applied in evaluating

the accessibility and relative transportation risk posed by alternate radioactive waste disposal sites. These guidelines suggest that the identification of an acceptable site should be sensitive to a number of transportation factors. For example, the application of available guidelines to the siting process suggests that the site should be accessible by roadways which:

- are not characterized by extensive height limitations on bridges or height limitations on underpasses;
- have adequate land and shoulder widths;
- are not characterized by numerous stops and heavy volume intersections;
- do not require extensive weaving or lane changes;
- do not pass through tunnels or over railroad crossings, where the potential for accidents is greatest;
- do not pass through heavily populated areas or nearby hospitals, schools, nursing homes and other facilities from which evacuations would be particularly difficult and the possibility of immediate exposure would be high;
- have emergency lanes so they are readily accessible by local emergency response personnel equipped with proper radiological monitoring equipment and other supplies;[17] and
- do not pass through local jurisdictions which, for whatever reasons, have imposed restrictions banning the transport of low-level radioactive wastes within their borders.[18]

Of course, the evaluation of alternative sites will not always result in the identification of a location vastly superior to other sites in terms of access. It generally will be necessary to choose between sites which are less accessible, but are served by better road or rail classes and present less exposure to people and property. In the event that the transportation risks posed by a particular site remain

unacceptable, steps should be taken by the host state to improve the local emergency response capabilities of those communities through which the bulk of the radioactive wastes are expected to pass.[19]

Footnotes

1. Sandia National Laboratory, Transportation of Radionuclides in Urban Environs: Draft Environmental Assessment, NUREG/CR-0743, Washington, D.C., NRC, July, 1980.

2. U.S. Nuclear Regulatory Commission, Final Environmental Statement on the Transportation of Radioactive Material by Air and other Modes, NUREG-0170, Washington, D.C., 1977.

3. J.D. McClure, et al., "A Review of U.S. Accident/Incident Experience Involving the Tranportation of Radioactive Materials (RAM)", SAND 80-0899 A, Albuquerque, N.M., 1982.

4. E.G.&G., Idaho, Inc., Low-Level Radioactive Waste Management Handbook Series: an Introduction, DOE/LLW-13Ta, Idaho Falls, ID, August 1983, p. 21.

5. Ibid, p. 6.

6. J.D. McClure, et al., "Accident-Incident History in the Transportation of Low-Level Waste since 1971", SAND 82-1417, Albequerque, N.M., 1982, p. 2.

7. U.S. General Accounting Office, The Problem of Disposing of Nuclear Low-Level Wastes: Where Do We Go From Here?, Washington, D.C. 1980.

8. E.G.&G., Idaho, Inc. Directions in Low-Level Radioactive Waste Management -- Low-Level Disposal:Currently Operating Commercial Facilities, DOE/LLW-6Tg, Idaho Falls, ID, 1983, p. 12.

9. U.S.D.O.T., A Review of the Department of Transportation Regulations for Transportation of Radioactive Materials, Washington, D.C., 1980, p. 24.

10. U.S.D.O.T., "Community Teamwork: Working Together To Promote Hazardous Materials Transportation Safety", Washington, D.C., May, 1983, p. 21.

11. Southeast Interstate Low-Level Radioactive Waste Management Compact, South Carolina Laws, Title 48, Chapter 47, Section 48-47-10.

12. Rocky Mountain Low-Level Radioactive Waste Compact, Colorado Revised Statutes, Title 24, Article 60, Section 24-60-2201.

13. U.S.D.O.T., FHWA, "Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials", FHWA-IP-80-15, Washington, D.C., USGPO, November 1980.

14. U.S.D.O.T., Research and Special Programs Administration, "Guidelines for Selecting Preferred Highway Routes for Large Quantity Shipments of Radioactive Materials", Washington, D.C., June 1981.

15. 49 CFR 177.810 and 177.825; and Appendix A to Part 177.

16. Transportation Research Board, Risk Assessment Processes for Hazardous Materials Transportation, NCHRP 103, Washington, D.C., TRB, November 1983.

17. City of Portland, Office of Emergency Management, "Establishing Routes for Trucks Hauling Hazardous Materials in Portland, Oregon", (Unpublished, January 1984).

18. The American Planning Association, "Truck Transport of Radioactive Materials and Wastes", (Unpublished, December 1983, pp. 30-36.

19. U.S.D.O.T., "Community Teamwork Working Together to Promote Hazardous Material Transportation Safety", Section 3.

3.5 Demography and Land Use

It is imperative that a low-level radioactive waste facility be isolated from population centers and sensitive or incompatible land uses. It is not only a matter of public health and safety, but also a political reality. The federal regulations do not address this issue with any specificity, except to say that projected growth and development and nearby activities should not interfere with the ability of the site to meet the performance objectives of the regulations. We believe that more detail is required to identify a suitable location for a disposal facility. The criteria we recommend are more specific than the federal

performance standards. Ours are based on siting criteria for hazardous waste facilities developed in Massachusetts and elsewhere.

The goal of these criteria is to prevent inadvertent human intrusion onto a site, to create buffer zones between the site and other land uses, and to ensure that the objectives of the federal regulations are met. These criteria would apply to any technology that could be employed in Massachusetts.

There should be no relaxation of standards for an above-ground storage facility as compared to a shallow-land burial site.

Criteria for Demography and Land Use

Proposed Criteria	Comparison with NRC 10 CFR 61	Comments
Projected population growth and development adjacent to a facility should not affect its ability to comply with performance standards. Low population density should be a prime consideration in the siting process.	Same	Facilities should be sited in areas which are expected to maintain low populations densities. A consideration that should be factored in is the anticipated effects on the host community's growth resulting from the influx of facility employees and secondary growth resulting from the influx. One caution to keep in mind is that rural communities may not always be capable of hosting a facility of this kind.
No low-level radioactive waste facility shall be located	Not specified	This criteria is designed to isolate the site from imcompatible land uses

Proposed Criteria	Comparison with NRC 10 CFR 61	Comments
within 1/2 mile of a residential or commercial zone as defined by the host community's zoning by-law.		and create a buffer zone around it. Optimally, a site should be located in a rural area that is or can be rezoned as an industrial area.
No low-level radioactive waste facility shall be located within 1 mile of sensitive receptor sites or land uses such as schools, hospitals, elderly housing, nursing homes, recreational areas, agricultural lands, parks, and city, state, and national parks.	Not specified	Sensitive receptors or lands uses must be isolated from such a facility in order to buffer the area against a serious accident or release. A Sensitive receptor is either an affected human population or a critical environmental resource.
For any facility there shall be readily available fire, police and medical emergency personnel; medical facilities; and readily available equipment and transportation routes to cope with emergency conditions.	Not specified	The facilities in some communities may not be prepared to handle the potential problems posed by a facility. Proper emergency facilities are essential.
The disposal site should not be located where nearby facilities or activities could adversely impact the ability of the site to meet applicable performance and environmental monitoring objectives.	Similar	Some of our recommendations are for stronger standards than those of the NRC. This is intended to eliminate the possibility of locating a disposal site near an incompatible industrial facility, for example.

3.6 Public Health

3.6.1 General Goals for Public Health Protection Criteria

Public health criteria for a state system of low level radioactive waste disposal can be thought of as having three related goals:

1. Protection of Individual Health - That no individual member of the public or worker bear an unreasonably high risk of adverse effects from radiation exposure;

2. Minimization of Overall Harm - That the aggregate health risk borne by citizens of the state as a whole be as low as is feasible; and

3. Community Equity - That no community in the state unfairly suffer real or perceived deterioration in the safety of its members for the benefit of others, as a result of needed changes in current arrangements for low level radioactive waste disposal.

Current NRC radiation protection standards are designed primarily to achieve the first goal, although there is at least some attention to the second goal. We propose public health protection criteria designed to give greater assurance that the second and third of goals will be achieved.

3.6.2 Background Discussion of Radiation Terms, Current Population Exposures and Radiation Risks.

Before listing the NRC requirements, some background discussion is needed to clarify the meaning of the radiation dosage terms used, and the significance of the numerical standards for health risks. Table 3.6-1 defines terms, and Table 3.6-2 summarizes average annual radiation dosage to the general

population from a number of sources. It can be seen from Table 3.6-2 that total current exposure averages about 200 millirems per person, with about half of this coming from "natural background" and the bulk of the rest from medical sources. Over 70 years of life, the total comes to about 14 rems.

In discussing the health risks from radiation exposure, the principal focus is usually on risks of cancer. There are other effects, notably in inducing some number of mutations - changes in the information coded in DNA and passed along to future generations. However, the numerical impacts are best documented for carcinogenesis, and current information on the public health significance of mutagenic effects does not suggest that it is grossly in error to make carcinogenesis the primary focus of social concern and control efforts. (For example, it has yet been difficult to detect excesses of adverse health impacts attributable to mutagenesis in the offspring of the survivors of the atomic bomb in Hiroshima and Nagasaki, whereas the carcinogenic effects in those directly exposed are quite apparent.[1] In part, this is due to the fact that specific mutations are very diverse, individually rare and difficult to detect.)

Although there is controversy on the subject of the appropriate rules for low-dose radiation projections, on the basis of what is known about the mechanisms of radiation-induced damage to DNA and resulting carcinogenesis, we believe it is very likely that the low dose health risks are approximately directly

proportional to dose at low dose levels. There should be no expectation that any finite dose of radiation can be absorbed without some incremental risk. Based on a range of different linear and linear-quadratic dose response models and data from the exposure of various human groups to relatively high dose levels (atomic bomb survivors, medical radiation, and radium watch dial painters) the total cancer mortality risk is likely to be between 0.7 and 6 cancers for every 10,000 person-rems of whole body low-dose exposure[2] (a person-rem would result from exposing 10 people to .1 rem to 100 people to .01 rem, etc.)

In combination with the data in Table 3.6-2, this suggests that each year the average current dose of radiation of 200 mrem (0.2 rem) from all sources brings with it an additional lifetime risk of (.7-6)X(.2)/10,000 = .14 - 1.2/10,000, or roughly between one in one hundred thousand and one in ten thousand. Similarly, the 14 rads of total cumulative lifetime dosage is likely to cause an extra cancer risk of (.7-6) X (14)/10,000 = (10 - 84)/10,000 or roughly between one in a thousand and one in a hundred. The "normal" radiation exposures we live with every day, therefore, may well be considered to be of appreciable public health significance. Appreciable additions to those exposures are an entirely legitimate subject for social concern and social efforts at control.

Table 3.6-1

Terms Used in Radiation Protection Standards

Curie = Quantity of radioactive material which undergoes $2.2X10^{12}$ disintigrations per minute

Roentgen = Unit of radiation which causes air to absorb 83.4 ergs (energy) per gram of air

Rad (also millirad, etc.) = Unit of absorbed dose; 100 erg/gm absorbed energy in the material of interest

REM = Unit of absorbed dose X QF ("quality factor" for biological effectiveness)

QF = Quality Factor; depends on type of radiation, dose-rate, dose fractionation, sensitivity of organ irradiated, and the effect studied

for gamma, beta radiation,	QF is about 1
for x radiation, neutrons	QF is greater than or equal to 1
for alpha radiation	QF is much greater than 1 (often about 20)

Table 3.6-2

Current Sources of Radiation Exposure to the General U.S. Population

Source	Person-rems/yr (total, United States)	Per Person (millirems)
Natual background	2.0×10^7	100
Medical Radiation	1.8×10^7	90
Nuclear Weapons (fallout)	$1.0\text{-}1.6 \times 10^6$	5-8
"Technologically enhanced" radioactivity	1.0×10^6	5
Nuclear power plants (normal operation)	$2.0\text{-}3.6 \times 10^4$	.1-.2
Consumer products	6.0×10^3	
Nuclear weapons production	165	
Total non-background	2.0×10^7	about 100

3.6.3 Summary and Discussion of Current NRC Radiation Protection Criteria.

The major NRC performance criteria designed to protect public health from radiation risks from the land disposal of low level radioactive wastes are found in Subpart C of 10 CFR Part 61:

Section 61.41 requires that

> Concentration of radioactive material which may be released to the general environment in ground water, surface water, air, soil, plants, or animals must not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the general public. Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as reasonably achievable.

Sections 61.42 and 61.44 are very generally-phrased requirements that

> - Design, operation and closure of the land disposal facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after active institutional controls over the disposal site are removed.
>
> - The disposal facility must be sited, designed, used, operated, and closed to achieve long-term stability of the disposal site and to eliminate to the extent practicable the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care are required.

Sections 61.43 imposes occupational and general public health radiation protection requirements that are essentially the same as for all other uses of radioisotopes regulated by the NRC:

> Operations at the land disposal facility must be conducted in compliance with the standards for radiation protection set out in Part 20 of this chapter... Every reasonable effort shall be made to maintain radiation exposures as low as is reasonably achievable."

Table 3.6-3

Principal General Radiation Control Requirements for All NRC Licensees

(From 10 CFR 20)

(Section 20.101) Limits on individual occupational whole-body radiation exposure of no more than 3 rem in any calendar quarter, and no more than 5 rem per year on a cumulative basis after age 18 (persons under 18 are limited to one tenth of this dose rate by Section 20.104).

(Section 20.105) Limits on exposure to the most exposed member of the genral public of no more than 0.5 rem per calendar year. Maximum radiation dose rates in unrestricted areas are set at 2 millirems (.002 rem) in any one hour and 100 millirems in any seven consecutive days, except if the applicant demonstrates that exceeding these short term limits is not likely to lead to violation of the one year/0.5 rem limit for any individual.

Limits on the air concentrations of specific radioactive materials within restricted areas (on site) (Section 20.103), and in unrestricted areas accessible to the public (Section 20.106). These "Maximum Acceptable Concentration" limits appear to be derived from calculations of the amount of specific radionuclides needed to deliver 5 rem to occupationally exposed persons over a calendar quarter, or 0.5 rem to members of the general public over a calendar year. There is also a similar set of requirements for radionuclide concentrations in drinking water.

Requirements for environmental monitoring (20.201), monitoring of radiation doses to workers (20.202), posting warning signs (20.203), instruction of personnel (20.206 and 19.12), security for stored radioactive material (20.207), limits on the amount of material that can be disposed to sanitary sewage systems (generally, the amount which, after dilution with other sewage, would meet the drinking water standards for radioactivity--20.303), limits on the amount of material that can be disposed of with ordinary trash (20.306), a manifest tracking system for waste disposal (20.311), and various record keeping requirements and requirements for emergency notification of NRC in case of unusual incidents that could potentially lead to substantial public exposure (20.4).

The main features of Part 20 are listed in Table 3.6-3.

In addition, 49 CFR 170 limits transportation-related exposures to the general public to 10 mrem/hour at 6 feet from the surface of the transport vehicle.[3] (The authors of one study computed a total transportation-related population dose of 9.5 rem per year for a model low-level radioactive waste facility in the East, based on an assumed population density of 300 people per square mile around the route, 200 miles of transport per day, an average transport distance of 400 miles by rail totalling 528,000 vehicle miles per year, and a population density of 300 people per square mile along the route.[3] The current situation, in which wastes are transported for longer distances, would be expected to lead to larger overall exposures.)

It is not the purpose of this report to attempt to critique all of the NRC standards limiting individual doses to occupational and non-occupational populations. However, current standards clearly allow risks that are not insignificant for maximally exposed individuals, particularly in the case of workers:

- The yearly limit for accumulation of occupational exposure at 5 rem per year allows a yearly increment to lifetime cancer risk of between 3/10,000 and 3/1,000. Few individuals are actually exposed at this maximum level in practice, but theoretically over a 40 year working lifetime, a 5 rad/year accumulation would translate into an added cancer risk on the order of 1-10%. (There have been proposals to lower the permitted occupational dose to 0.5 rads/year, but there is no immediate prospect for this to be adopted at the national level.)

- Similarly, the yearly limit of 25 millirem (.025 rem) for a maximally exposed member of the general public from land disposal would allow a yearly increment to cancer risk of between two in a million and two in a hundred thousand. Were this dose level to continue for 70 years, the total individual risk would be between one in ten thousand and one in a thousand (The .5 rad per year limit for the general population in the overall NRC licensing standards, which appears to be the basis for calculations of maximum permitted air and water concentrations, would allow dose rates of 20 times these levels from radionuclide-using facilities not engaged in waste disposal.)

Whatever the fairness of imposing these levels of added risks on maximally exposed individuals, it certainly should not be assumed that mere compliance with these individual dose, air and water concentration standards alone necessarily will reduce collective radiation risks to affected workers and communties to insignificant levels. (In the past, the focus on individual worker exposure limits has led to the abuse of hiring temporary workers for a day, giving them a quarter's worth of radiation dosage, and discharging them.) In the case of community exposures, there are not the same kinds of measures to redistribute dosage, but collective risks could add up if widely spread. Even the relatively stringent 25 millirem per year individual limit for the waste disposal facility itself, if complied with in such a way that 100,000 people were exposed to 10 millirems each per year, would be expected to produce an ultimate total of one to several cancers per decade.

In the NRC regulations, aggregate exposures of both workers and the general public are addressed by the "As Low As Reasonably Achievable" (ALARA) language of Section 61.43 and elsewhere. The very general wording used provides the NRC with a flexible tool

for mandating the implementation of controls deemed to be "reasonable" in light of changing technology, costs, and social standards, but it unfortunately provides little concrete assurance to interested communities about the overall level of risk they will be required to bear.

Further, from the standpoint of a community contemplating acceptance of a waste facility, it fails to address the social equity of the distribution among communities of risks and benefits from activities that general low level waste. There can be a lingering suspicion that, despite the efforts made at control, the local community will suffer harm for the benefit of others. The fact that the harm comes in the form of a dificult-to-grasp numerical risk of a dread disease means that there may be continuing discomfort and resentment even if there are substantial economic benefits to the communities that are perceived to be affected.

3.6.4 Suggestions for Additional Public Health Criteria.

To better address the concerns for limiting aggregate harm and promoting both real and perceived community equity from a system of low level radioactive waste disposal, we suggest:

- that there be a defined level of total dose in person-rems per year specified for the waste handling and disposal system as a whole (including storage by generators, volume reduction by incineration or other means, and transportation), at least for general population exposures. Consideration also could be given to setting

analogous aggregate occupational exposure limits, although this might raise difficult legal jurisdictional issues. Total dose limits could be selected to reflect the expected performance of available or foreseeable technology. Such a standard, if relatively stringent, also would provide an incentive to locate the more hazardous components of the waste disposal system in areas where they would expose fewer people.

- that there be initial and periodic analysis and public discussion of estimated population risks from the system, disaggregated so that the impacts on local communities could be distinguished. Communities can make an informed judgement about the acceptability of risks and control measures only if they receive a good initial analysis of those risks, and continuing updates on the actual levels of risk incurred as time passes.

- that there be a novel net health benefit requirement - that the licensee undertake or finance public health measures that are conservatively calculated to prevent 10 to 100 times the aggregate excess health risk incurred in identified communities over the "baseline" of present radiation exposure risks. This could be most unambiguously accomplished within the realm of radiation protection itself, for example, if the licensee were to search out local homes with excessive "natural" radioactive radon daughter levels and pay for improvements to reduce those levels. (The indoor radon exposure problem is not currently widely appreciated by the general public, but national estimates suggest it may be causing an annual toll in the thousand of cases of lung cancer. The radon originates from uranium in rocks, soil, and building materials, and can be conveyed into the house either through air seepage or well water. An estimate from Maine, where the problem has achieved more public visibility, indicates that as many as 20% of the houses may have airborne radon levels of 4 pCi/l, which is calculated to be sufficient to cause a 1% change of lung cancer over a 60 year period of exposure.[4]) Credit for prevention benefits also could be earned by making emissions-reducing improvements at the sites of the generators of low level wastes. Alternatively, other proven public health promotion measures could be selected in collaboration with the communities.

To our knowledge, the latter type of requirement has never been suggested before. By structuring the system so that there are no "losers" with respect to health risks, we think it is possible that both legitimate health and economic/property value

concerns of local communities could be addressed in a way that could be judged fair to everyone. It also might prove more acceptable to communities to have a health-for-health transaction than to have a dollars-for-health transaction by means of a simple monetary settlement in recognition of community health risks.

Footnotes

1. Beebe, G.W., "Ionizing Radiation and Health", American Scientist 70, pp. 35-44.

2. Committee on the Biological Effects of Ionizing Radiation, The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980, National Academy Press, Washington, D.C., 1980, data from continuous lifetime exposure in Table V-4, p. 147.

3. Macbeth, P.J., et al., Evaluation of Alternative Methods for the Disposal of Low-Level Radioactive Wastes, Ford, Bacon and Davis Utah, Inc., prepare for the Nuclear Regulatory Commission, NUREG/CR-0680, 1979, Appendix C.

4. Hess, C.T., quoted by Chilund, C., "New England's Radioactive Nemesis", The Boston Globe, March 27, 1983, p. 41 and 44.

3.7 Geologic, Hydrologic and Surface Water Criteria

The geologic characteristics of Massachusetts and its location in the humid Northeast militate against the use of shallow land burial as an effective disposal option. A satisfactory land disposal facility could be designed at a few locations in Massachusetts but only with extensive engineering

and concomitant high costs. There would be an ever-present uncertainty, moreover, in spite of the sophistication of the facility, that because of the heterogeneity of our glacial deposits, leaks could occur into the groundwater and escape the site without detection by the monitoring system. This is the principal disadvantage of land disposal, the inability to visually inspect the entire outer surface of the disposal units and the consequent total reliance on a finite number of discrete monitoring elements to detect accidental discharge to the soil and groundwater.

An above-ground disposal system, on the other hand, provides full visual inspection of the outer surface of the primary disposal units, and in addition, if provided with a secure lower level, provides a secondary containment area in the event of spills. This area allows ample time to institute remedial action. The ability to visually detect, contain and correct any accidental discharge of radioactive material prior to its introduction into the subsurface is one important advantage of an above-ground disposal facility. The elimination of the uncertainty of a discharge occurring also confers another important advantage. It would allow more sites to meet the hydrogeologic criteria. This, in turn, would give greater flexibility in site selection.

The geologic and hydrologic siting criteria of the NRC provide a broad, thorough and well thought-out set of guidelines for the land disposal of radioactive waste. There are problems

in applying certain of the criteria in Massachusetts, however, because of the geologic conditions prevailing in the Commonwealth. Compliance with some of these NRC criteria is possible with sufficient engineering effort. Two of the criteria, however, cannot be met regardless of the engineering effort.

The following is a description of those NRC criteria which present compliance problems in Massachusetts and the reasons for the problems.

The disposal site must be capable of being described, modeled, analyzed and monitored.

This requires homogeneity of the various strata and a simple stratigraphy. With the exception of the lower portion of the varved clay deposits in the Connecticut Valley and the core of drumlins, this criteria is not attainable in Massachusetts or in New England for that matter. The remaining glacial deposits, fluvial, lacustrine and tills are highly variable. Predictions based on even extensive field exploration programs are still subject to uncertainties and errors. An especially difficult problem is the detection of thin, but moderately to highly permeable horizontal strata in otherwise low permeability deposits giving rise to unpredictable lateral flow paths.

<u>The depth to the water must be sufficient to prevent groundwater intrusion into the waste</u>.

Excluding the Cape and southern Plymouth County where there are thick, well drained outwash and morainal deposits, the principal surficial materials in Massachusetts consist of ground moraine till and shallow fractured bedrock. The water table in the till ranges from a few feet below the ground surface to 10 to 15 feet in depth. The aquifers within the outwash and morainal deposits of Cape Cod and southern Plymouth County are the only source of water for the residents of these areas.

In order to minimize the land area needed for a disposal site and to provide a sufficient thickness of cover to prevent infiltration of surface water, to deter rodents from burrowing into the buried wastes and for a number of other reasons, disposal trench depths on the order of 20 feet are necessary. This requirement would place the trenches below the water table and within the zone of water table fluctuation in most of Massachusetts, which is specifically prohibited in Section 61.50(7) of the NRC regulations. In addition, portions of the bottom of the trenches would lie in fractured bedrock. Sites in these areas could be made suitable with careful selection and a great deal of engineered drainage features and rock grouting. It would be very costly.

In addition to Cape Cod and Plymouth County noted above, there are some other localized geologic features with sufficient

area and a water table deep enough to meet the water table criteria. These are the kame plains and kame deltas found scattered though the Commonwealth. These deposits consist of commercially valuable sand and gravel, however, and the number of available deposits is disappearing rapidly as the economic incentives to mine these materials increases. In addition to being well drained, these deposits are also level and require virtually no grading. These two features make them especially attractive as building sites, which has further depleted their number. There are very few left.

Finally we should consider the clay deposits in New England. They consist of: (1) the fresh water varved clays found in the Connecticut Valley and a few small generally thin occurrences at various other locations within the state; and (2) the marine clays that extend from Boston northward along the coast in the populated North Shore area. The water table in these deposits is for all practical purposes at the surface. The NRC criteria indicate that burial below the water table in clay materials is acceptable if groundwater flow is slower than the rate of molecular diffusion. This implies a horizontal permeability of less that 10^{-6} to 10^{-7} cm/sec. Some of the clays do have vertical permeabilities in this range, but due to horizontal stratification and the presence of silt and even fine sand layers, the horizontal permeability is significantly higher. The hydraulic gradients in clay deposits, though, are generally very low so that the seepage velocities, while not quite as low as the

rate of molecular diffusion, still may be low enough to keep flow within the groundwater system for the several hundred years required for reduction in radioactivity prior to release to surface waters.

The problem, as previously noted, is the lack of homogeneity of these deposits and the uncertainties in predicting the stratigraphy and therefore the horizontal flow rates.

Even greater problems are the lack of virgin, undeveloped sites on clay deposits. As noted previously, the clays that do occur are along the coast in the populated North Shore area and in the equally populous Connecticut Valley lowland.

Residence time of radionuclides in the groundwater must be greater than 500 years before discharge into surface waters.

It is possible that this criteria might be met for sites located in clay deposits within the Commonwealth as noted above. It could not be met in any other location. Seepage velocities in ground moraine tills range from 10 to 20 feet per year. Moreover, in the recommended 500 year period for the wastes to decay to safe levels, radionuclides could travel 5,000 to 10,000 feet. In ground moraine till areas, shallow groundwater flow seldom travels farther than a few hundred feet before discharge to surface waters of some sort - if not to a stream or brook, then to a small rill and thence to a stream or brook.

In stratified sand and gravel deposits, seepage velocities range from 100 to as much as 500 feet per year. In 500 years, radionuclides could travel 10 to 25 miles in these deposits if confined to shallow groundwater flow. This, of course, is not possible in Massachusetts with our extensive network of surface streams.

CRITERIA FOR

GEOLOGY, HYDROLOGY AND SURFACE WATER

LAND DISPOSAL

Proposed Criteria	Comparison with NRC 10 CFR 61	Comments
Site must be capable of being accurately described, modeled, analyzed and monitored.	Same	Strict interpretation would eliminate all sites within Massachusetts.
Long term stability of the site and the disposal facility must be assured.	Same	Geologic instability, from seismic activity for example, may result in the breach of waste disposal units, thereby releasing waste into the environment.
The site must not be located in an area having known natural resource value.	Same	Sites should be avoided if they have mineral deposits, forest resources or other marketable resources. Exploitation of these resources may adversely affect the site's ability to meet performance standards.

Proposed Criteria	Comparison with NRC 10 CFR 61	Comments
Preferred site would be located in an area with a low population density, and existing industrial area where groundwater and aesthetic degradation have already occurred.	Differs	10 CFR 61 stipulates an area of low population density removed from urban centers which basically implies location in an undeveloped rural area.
Site must not be located in the recharge area of an existing or developable future water supply aquifer whether or not it has been legally designated as a "sole source aquifer".	Not specifically stated, but implied in a number of criteria.	This important criterion eliminates much of Massachusetts from consideration for land disposal of radioactive waste, but the criterion is needed to protect present and potential drinking water supplies, whether formally designated or not.
Depth to the water table must be sufficient to prevent groundwater contact with the buried waste during the life of the facility.	Same	Compliance in Massachusetts possible only with extensive and costly engineered subsurface drainage features. This criterion is needed to protect groundwater supplies from radionuclide contamination.
Residence time of radionuclides in the ground water must be greater than 500 years before discharge into surface waters or into water supply wells.	Implied	Actual residence time is not stated in 10 CFR 61 but residence time sufficient for radioactive decay to safe levels is implied. This criteria cannot be met in Massachusetts. Preferable to create barriers that totally insulate groundwater from radionuclide contamination than to rely on dilution and decay over time.

Proposed Criteria	Comparison with NRC 10 CFR 61	Comments
Site should be beyond the limits of the 100 year flood plain, coastal high water hazard area or wetland.	Same	These are sensitive environmental resources which serve as natural flood containment areas, plant and wildlife habitats and recharge areas. They also are areas where water can infiltrate buried waste.
Facility should not be constructed in fractured rock.	Not specified	Extremely important as rock fractures provide open conduits for groundwater flow and rapid contaminant dispersal.
Must be demonstrated conclusively that sites located in clay-type soils do not contain conductive horizontal strata.	Not specified	It might be possible to correct this problem by engineering cut-offs where these features are encountered during construction. These soils have exacerbated radionuclide migration problems elsewhere.
Facility must not be located in areas prone to slope failures or erosion.	Same	Many of the problems at the three failed sites occurred due to erosion and slope failure which destroyed the integrity of the trench caps. For example, gully erosion at West Valley drained runoff toward the trenches.

ABOVE GROUND DISPOSAL

Proposed Criteria	Comparison with NRC 10 CRF 61	Comments
Long term stability of site and structure must be assured.	Implied	Consideration should be given to using natural granitic building stone for the structure rather than reinforced concrete. Geologically unstable areas must be avoided.
Structure must meet or exceed the seismic design criteria of the Massachusetts Building Code.	Not specified	The Massachusetts Building Code contains criteria to ensure that buildings withstand seismic disturbances. At a minimum, waste disposal facilities should meet this criteria.
Preferred site must be located in a low population density, existing industrial area.	Not specified	See comment under Land Disposal.
Structure must not be in the 100 year flood plain, coastal high water hazard area or wetland.	Same	See comment under Land Disposal.
Structure must not be located in an area having known natural resource values.	Same	See comment under Land Disposal.
Facility must not be located in areas prone to slope failures or erosion.	Same	Erosion and slope failures could threaten the structural integrity of the facility.

Proposed Criteria	Comparison with NRC 10 CFR 61	Comment
Site must not be located in the recharge area of an existing or developable future water supply aquifer whether or not it has been legally designated as a "sole source aquifer".	Not specified	The hazardous waste regulations prohibit new land treatment facilities "on land which is overlying an actual, planned or potential" underground drinking water source or within the flowpath of an underground drinking water source. (See 310 CMR 30.701).

3.8 Air Emissions

Air emissions are of importance because air is a relatively short-term pathway to human exposure. Groundwater pathways often dominated earlier projected risk estimates for waste disposal in analyses that project impacts over 1,000 years[1] but in a properly designed shallow land burial site, migration to aquifers that might be used for drinking water (after an assumed lapse of institutional control) should take at least decades if not longer. Air exposures are, of course, a primary focus for risk assessment for above-ground storage systems in structures that prevent access to groundwater, at least while the building can be maintained and monitored.

There are a number of processes that lead to air emissions of radionuclides:

- Biological decomposition -- particularly a concern for tritium, an ^{14}C, which are converted to radioactive water, carbon dioxide and hydrocarbons. This can occur while

wastes such as animal carcasses are awaiting disposal, and after disposal. Measurements recently made of outgassing at the West Valley, New York site suggest an ^{14}C emission of slightly less than 1/1,000th of the buried ^{14}C per year.[2]

- Radioactive decay of certain radionuclides to radioactive noble gases. (Both ^{85}Kr and ^{222}Ra have been observed in trench gas at the West Valley site.)

- Chemical or physical volitilization of organic compounds and selected inorganics (e.g. iodine).

- Incineration of institutional low-level wastes. Incineration now occurs at two or three locations in the state.[5] Incinerators have been licensed with the requirement that annual average radionuclide concentrations in the stack effluent be less that 10% of the NRC's "maximum permissible concentrations" (MPC's).[3] Model calculations, based on the composition of institutional low level waste in North Carolina, indicate that incineration would lead to aggregate stack air concentrations of tritium, ^{14}C, ^{35}S, and ^{45}Ca about 7 times the MPC levels, but annual average ground concentrations of about 1/1000 the MPC levels after dilution.

- Short run spillage and dust emission. One study of radiological impacts of low level disposal facilities cited previous experience that about one in every 10,000 drums of waste is dropped, and that this leads to airborne emission of about 1/1000th of the contents.[4] Combined, these two numbers imply that about one ten millionth of the waste processed by conventional techniques may be emitted from the site.

- Long term dust emissions. Dust emissions are included in projections of airborne exposures, due to initial spillage of material and various processes that might transport waste to the surface over long periods of time.[1]

- Fires. We do not know of any cases of fires at low level radioactive waste disposals sites. Incineration of some wastes and other measures (e.g. compaction) to reduce waste volume have the effect of reducing fire risks, but the potential may exist for some appreciable emissions of radionuclides, should a fire occur at a low level waste disposal facility.

The discussion in Section 3.6 has covered the basic form and derivation of NRC's maximum acceptable concentration limits for air. The basic difficulty with any system of control that places

primary reliance on simple concentration limits is that, implicitly, dilution and spreading of material over a wider area is treated as an effective control measure. Absolute emission reductions are indeed encouraged under the general "As Low As Reasonably Achievable" standard, but it is difficult to know exactly what this means in practice.

We suggest that

- Basic air emission standards for facilities that are part of the waste disposal system (including interim storage by generators) should be derived from overall population radiation dosage goals, as indicated in Section 3.6. The emission standards should be set in terms of the total activity of various radioisotopes released per unit time (e.g. millicuries per day) rather than concentrations.

- There clearly need to be monitoring requirements for air emissions:

(a) at the stack (for incinerators), over trenches (for burial facilities) or at building ventilation exhaust ducts (for storage buildings) to check on compliance with emissions standards;

(b) in selected locations in communities, to confirm the validity of air dispersion models used in calculating population dosage; and

(c) in workplace air, for worker protection.

- In addition, the engineering of the facility and operating system should be designed to control dust emissions from spillage events as much as practicable. The existing literature suggests that above-ground storage facilities are likely to have inherent advantages in this regard[4] (as some spills will occur indoors and away from wind), but other measures may be possible to minimize this mode of emissions.

- Fire prevention procedures and equipment (e.g. sprinkler systems) should be designed after an appropriate review of available technology, for the waste disposal facility itself, vehicles engaged in transportation, and interim storage places at the sites of waste generation.

Footnotes

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2. Kunz, C.O., "Radioactive Gas Production and Venting and Low-Level Radioactive Burial Site.", Nuclear Chemical Waste Management 3, pp. 185-90, 1982.

3. Couch, N.W., et al., "Radionuclide Emissions from Incineration of Institutional Low-level Radioactive Wastes", Health Physics 42, pp. 871-3, 1982.

4. Macbeth, et al., Evaluation of Alternative Methods for the Disposal of Low-level Radioactive Wastes

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3.9 Biota

One of the "inadvertent" pathways for potential contamination results from the intrusion of a waste site by burrowing animals which subsequently come into contact with the buried waste. Similarly, plants can absorb radionuclides through their roots and then release it into the atmosphere through evapotranspiration. Radionuclides can enter the food chain as contaminated plants and animals are consumed by species which are higher on the food chain. This is a problem only where land burial is the mode of disposal. Although an engineered disposal facility effectively would prevent inadvertent intrusion, a well-designed and operated land burial facility also could reduce the potential for spreading contamination in this manner. A combination of stabilized, liquid-free wastes in drums and sufficient soil cover over an impermeable trench cap can minimize this problem. These criteria are addressed elsewhere in the report (Section 3.3 and Section 3.10).

3.10 Engineering & Design

The NRC has established some performance standards for the engineering and design of a shallow-land burial facility. These deal with issues such as the integrity and stability of the disposal units and their covers, drainage in and around the trenches, intrusion, on-site traffic, construction methods and design codes. The goal of these standards is to ensure the isolation of the buried wastes from the environment. The site must be able to withstand natural forces such as flooding and erosion in order to prevent the exposure of the wastes to water or air. Many of the problems that have occurred at other sites resulted from design flaws that led to a breakdown in the barriers which were intended to isolate the wastes.

In Massachusetts, the ability of a land disposal site to insulate the wastes over the period of time required by the NRC regulations is hindered by the geology and the climate. Generally, the water table is too high to allow land burial with an adequate buffer between the buried waste and the groundwater. In addition, the annual precipitation of approximately 45" presents many opportunities for water to come into contact with the buried waste. Engineered structures can provide an easier mechanism for meeting the NRC performance standards. In our list of criteria, notations are made which show those instances where engineered structures are preferable to land disposal.

Criteria for Engineering and Design

Proposed Criteria	Comparison with NRC 10 CFR 61	Comments
License application must include descriptions of design features related to water infiltration; integrity of trench covers; structured stability of backfill, wastes and covers; waste contact with water; site drainage; reduction of long-term maintenance; and inadvertent intrusion. Additional information should include how the criteria meet the performance objectives; what natural events the facility is designed to withstand; what design codes and construction methods are used; waste handling procedures; on-site traffic and drainage systems; and methods of controlling waste contact with surface groundwater.	Same	Water infiltration into trenches and the subsequent trench cover subsidence, water infiltration, and leaching was one of the leading causes problems at the three failed sites. These lessons, coupled with the site characteristics in Massachusetts, lead to a conclusion that these standards can most easily be met with engineered disposal. Water contact with with wastes can be virtually eliminated. Long term maintenance has less immediacy (although constant monitoring is always required) and inadvertent intrusion can be avoided.
The wastes should not come into contact with water at all, and the standard should be total isolation until until the wastes are no longer "radioactive".	Not specified	Reduction of the radioactivity over time as it migrates through the groundwater should not be acceptable. Once again, this is achieved best by engineered facilities.
Facility must be able to withstand 100 year storm/flooding events.	Not specified	Engineered facilities can withstand these events better.

Proposed Criteria	Comparison with NRC 10 CFR 61	Comments
Surface features must be designed to direct water away from waste while minimizing erosion.	Same	Erosion is a major problem at the three failed sites. Gully erosion directs water to the trenches. Sheet erosion strips away the trench covers.

3.11 Facility Operation and Monitoring

3.11.1 Facility Operation

Proposed management of a facility is the key to the success of any waste treatment or disposal site. Partial responsibility for the failure of the three shallow-land burial sites has to be placed on mismanagement or poor operating procedures. When combined with an unsuitable site, the result can be disasterous. Adequate site selection alone, however, will not ensure a trouble-free facility. Therefore, we believe it is necessary to discuss some aspects of facility operation.

The NRC regulations cover facility operation in several places. They require waste be segregated by class and that wastes of different classes should be disposed of in separate disposal units. Wastes must meet requirements for land disposal as outlined in Section 61.52 of the NRC regulations.

In many cases, we recommend standards which go beyond those in 10 CFR 61. Additional operation issues need to be addressed and since the NRC regulations are for shallow-land disposal only,

new standards must be developed. All of them, however, are applicable to any technology.

Criteria for Facility Operation

Proposed Criteria	Comparison with NRC 10 CFR 61	Comments
Facility operator shall prepare and administer a comprehensive worker orientation and training program.	Not specified	Human error is an ingredient in many problems occuring at these and similarly related facilities. A required training program can help to minimize human error as a complicating factor. This is required in the hazardous waste management fields. (See 310 CMR 30.516 for details of plan).
Remedial action plans shall be prepared to prevent and minimize hazards to public health and safety from any sudden or non-sudden releases of contaminants.	Not specified	Emergency situations must be anticipated and planned for during every phase of facility operation. It is also important that these plans be coordinated with local police, fire, and health officials. For details on contents and implementation of such a plan see 310 CMR 30.520-524.
Efforts shall be made to minimize human intrusion onto a site, particularly intentional intrusion.	Partially addressed	The current NRC regulations do not cover intentional intrusion. In any case, barriers such as fences could be constructed to isolate the site from intentional or unitentional intrusion.

Proposed Criteria	Comparison with NRC 10 CFR 61	Comments
Records shall be kept detailing the quantities, physical characteristics, radionuclide content, radioactivity, and on-site location of deposited waste materials.	Not specified	Among the problems that occurred at Sheffield was the incomplete records of what materials were were placed in which trenches. This made effective remedial action difficult.
Class A, B, and C wastes must be segregated from each other and disposed of separately.	Same	This should be done regardles of the disposal technology employed.
Class C wastes must be protected against intrusion for 500 years.	Same	These wastes have long half-lives and high radioactive concentrationss which require long-term isolation.
Wastes must be emplaced in a manner that maintains package integrity.	Same	Subsidence of trenches results, in many cases, from decomposed containers and lack of adequate fill around buried material. Stable containers should be used and buried in orderly fashion. In engineered disposal this becomes less of an issue.
The boundaries and locations of each disposal unit must be mapped and marked.	Same	This will enhance any mitigative measure needed when a release has been detected by identifying the location of the waste.

Proposed Criteria	Comparison with NRC 10 CFR 61	Comments
A buffer zone must be maintained between buried waste and site boundary and beneath the disposed waste.	Same	Buffer zones around the site are addressed in more detail in Section 3.5. As we have indicated elsewhere in this report, it would be difficult to achieve an adequate buffer zone beneath the waste with the climate and geology of Massachusetts. Engineered storage would allow greater flexibility with respect to buffer zones.

3.11.2 Monitoring

Monitoring, both on and off-site, is required to detect the migration of any contamination so that corrective measures can be taken before irreparable environmental degradation occurs. This should take place at all phases of the operation. Initially, monitoring data will be used to established a baseline of information about the ambient air, water quality, and geohydrology of the site. During operation and after closure, monitoring data is used to detect releases.

The objectives of an environmental surveillance program are to:

- establish ambient levels of radioactivity;
- identify the type, potential pathways and modes of exposures of contaminants, establishing the rate of movement of contaminants, and detecting changes and evaluating trends of radioactivity in the environment;
- assess the exposure to humans and the ecosystem from radioactive materials;

- demonstrate compliance with all license requirements;

- maintain a data base and records system for all phases of facility operations;

- assess impact of site and waste stabilization activities;

- evaluate effectiveness of site closure; and

- assure continued confinement of radioactive waste materials.

Table 3.11.1 lists general criteria for environmental surveillance programs for low-level waste burial grounds. Many of these criteria are also applicable to other technologies, although the placement of monitoring devices may vary. For example, in an engineered above-ground structure, more emphasis should be placed on monitoring the environment inside the barriers since leaks will be detected there first. Action can then be taken to correct the problem. Even this type of structure requires monitoring outside the facility to ensure the isolation of all contaminants from the environment.

Criteria for Monitoring

Proposed Criteria	Comparison with NRC 10 CFR 61	Comments
Monitoring for establishing baseline data during license application process shall be undertaken over a 12 month period.	Same	The 12 month monitoring period will take into account most seasonal variations in the environment.

Proposed Criteria	Comparison with NRC 10 CFR 61	Comments
A monitoring program shall be established for the construction, operation, and closure phases of the facility's design life in order to evaluate environmental impacts and the need for mitigative measures.	Same	For details as to how this can be achieved, see narrative sections 3.8 and 3.11 and Table 3.11-1.
Monitoring should be installed without destroying the integrity of the site.	Not specified	Monitoring wells placed in areas that will produce fractures in bedrock, for expample, is counterproductive.
Access to land off-site should be arranged so that those areas can be monitored.	Not specified	This is especially important once the migration of waste material has been detected outside the disposal units. Off-site contamination has occurred at the other sites.

TABLE 3.11-1

General Criteria for LLWBG Environmental Surveillance Programs(a)

- A site-specific exposure pathway analysis should be performed for the potential radionuclide migration paths shown in Section 2.7.1 and 2.7.2. As a minimum, these should include the maximum exposed individual and the population within a 10 km radius of centroid of the site:
  - for "normal" or routine operations (including occasional breaches of radwaste containers);
  - for "accident" or unusual events leading to release of or enhanced migration of buried radioactivity.
- The exposure pathway analysis should be documented, with data references and local assumptions clearly distinguished, and with critical nuclides, pathways, and population groups described.
- Every exposure pathway should be documented, with data references an local assumptions clearly distinguished, and with critical nuclides, pathways, and population groups described.
- Every exposure pathway should be routinely measured which, as determined by the site-specific exposure pathway analysis, may contribute more than 1 mrem per year to the whole body or specific organ dose of individuals or critical population groups. (b)
- For critical pathways, a minimum of three locations should be routinely measured or sampled, including the location of greatest potential exposure and the nearest location of routine human occupancy.
- "Background" or "control" location measurements should be taken for every critical nuclide/pathway combination for which environmental measurements are made.
- Routine radioanalytical techniques should have minimum detection limits no higher than those equivalent to the 1 mrem/yr. dose criterion.
- Sampling or measurement intervals for each critical nuclide/medium combination should not exceed twice the half-life of the nuclide to be measured or one year, whichever is less.

- Where significant periodic variations in environmental concentrations may be expected, samples or measurements should be either continuous or at an interval less than half the expected peak-to-peak interval.

- Gross radioactivity analyses should be used only as trend indicators, unless supporting analyses provide a reliable relationship to specific radionuclide concentrations.

- Dose calculations from direct environmental measurements should be based only on statistically significant differences between the point of measurement and background (or control) data. For this purpose, statistical comparisons should be made at the 95% confidence level.

(a) Based in part on Table 3.2 of ERDA 77-24 (Ref 4).
(b) One-fifth of environmental dose limit proposed by NRC for decommissioning activities (Ref 33).

Taken from:
Denham, D.H., Technology, Safety and Costs of Decommissioning a Reference Low-Level Waste Burial Ground: Environmental Surveillance Programs, 1981, pp. 2-16.

3.12 Site Closure and Long-Term Care

The final phase of the low-level radioactive waste management process is to ensure that long-lived wastes remain isolated from the environment long after the disposal facility closes. Environmental monitoring and site maintenance procedures should continue over time so that releases can be detected and treated early - before the environmental damage occurs. Since a facility is designed to prevent environmental degradation for several hundred years, it is imperative that this responsibility is not neglected, even though it is difficult to guarantee that the original owner will control the site for that period of time. The original developer of the facility, or any subsequent owners/operators should be required to set aside funds for this purpose. Efforts should be made to prevent the government from acquiring the responsibility by default. Recent experiences have shown that it can be a very expensive acquisition. The criteria listed below outline some of the issues which should be addressed when considering the licensing of a facility.

Criteria for Site Closure and Long-term Care

Proposed Criteria	Comparison with NRC 10 CFR 61	Comments
Developer shall prepare a site closure plan detailing environmental monitoring plans (criteria in Section 3.11), and a funding mechanism for site	Not specified	This plan should indicate who will be responsible for site closure and long-term care, how the monitoring will be accom-

Proposed Criteria	Comparison with NRC 10 CFR 61	Comments
closure implementation and remedial action.		plished, and how it will be funded. It must be identified early and the funding mechanism should be established once an operating license has been obtained.
Independent inspections should be encouraged to ensure that monitoring is in place, to detect problems, and, if there are problems, to plan remedial action.	Not specified	The Commonwealth or some party other than the facility owner/ operator should conduct independent inspections to verify monitoring results.

4.0 Public Participation and the Siting Process

The experience of Massachusetts and other states in siting hazardous waste management facilities sheds some light onto the elements that constitute a successful siting process. The common demoninator in an attempt to site any kind of controversial facility (jail, airport, halfway house, hazardous waste treatment plant, and so forth) is public participation at every step from conception through closure. In order for the public to view a siting process as credible, it must be as involved in the process as the developer.

The public should be responsible for the selection of consultant teams hired by the government for various phases of work planning and policy formulation. The opportunity to shape the scope of work and make recommendations on regulations will further enhance the credibility and quality of the siting process. It is important to involve all interested parties such as industry and the medical and scientific communities.

Yet the list of siting criteria is only part of a siting process. The public should be involved in measuring potential sites against those criteria, and in evaluating specific facility proposals.

Beyond that, the public can play a very significant role in planning the specific project if any is approved, the operation of the facility, and the monitoring of the site. The selection

of suitable sites, technologies, and developers will have impacts that affect the environment, public health, and the socio-economic character of the host and abutting communities. By including the public at the outset of the planning process for a specific facility, the relationship between the developer and the public may be cooperative rather than adversarial. The affected communities must be able to trust and work well with the developer in order to facilitate the siting process. The hazardous waste facility siting process has not been particularly successful in this regard, and every proposal has been bitterly opposed, in part due to a perception that the host community is thrust into a process to which it is not a party until a developer proposes its plant.

Ultimately, the success of siting criteria is measured by whether there is widespread trust and public acceptance of the standards, the agencies administering them, and the facilities, if any, approved.

5.0 Conclusion

It would be difficult to find a more challenging environmental issue than the siting of a low-level radioactive waste disposal facility. There is a great deal of pressure to site a facility as a result of the Low-level Radioactive Waste Policy Act of 1980. Regardless of the options exercised by the Commonwelath with respect to entering a compact or not, a credible siting process must be developed. Creating a list of siting criteria is the first step in this process, so that feasible sites can be identified. A credible siting process requires a great deal of citizen imput, which has been the case thus far.

The criteria included in this report is the culmination of a large amount of work over a short period of time. The literature search we conducted revealed over 80 sources of information. We examined the histories of the other shallow land burial sites to identify the problems that existed so that we could recommend criteria that would avoid repeating past mistakes. We interviewed experts representing all parties in this issue, including a visit to Albany to talk to individuals directly involved in the West Valley problem. We believe we have developed a comprehensive list of siting criteria that could result in a publicly acceptable facility, should one be located in Massachusetts. We look forward to having this report scrutinized at the April public meetings. The feedback will be helpful in applying these criteria to potential sites.

Massachusetts now generates more low-level waste that any other state. Approximately 60% of the waste by volume is Class A waste. Although not all the waste in this category will have very short half-lives, most will decay within a couple of years. An option that should be considered is for the Commonwealth to encourage on-site storage for these short-lived wastes. The advantages are the lower disposal costs and a reduced risk of accidental releases during packaging and transportation. The volume reduction will place less of a burden on the disposal facility.

Once waste material is placed in a disposal area, it should stay there barring an emergency which necessitates the retrieval of the wastes. The facility must be engineered and construction to stand the test of time. Therefore, it is imperative that we avoid making the mistakes of the past. Greater expenses may be incurred during the design and construciton phases of the project, but they appear miniscule compared to the tremendous outlay required when an undetected leak contaminates the groundwater supply. The combination of stringent site suitability characteristics with state-of-the-art management techniques will begin to provide us with some basic assurances that the wastes we dispose of today will not threaten our health at a later date. Public acceptance of a facility hinges on these assurances.

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